Assessment of the Static Component of Aerobic Exercise: A Comparison of Exercise Using Cycle and Treadmill Ergometry, Hip Extension Exercises With or Without Gliding, and Gliding Video Workouts

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ABSTRACT

Four subjects, whose ages averaged 24.3 years, were examined to assess the isometric component of dynamic exercise during the following 4 conditions: treadmill running, cycle ergometry, aerobic exercise following a video, and during hip extension exercise (lunges). The isometric component of exercise was characterized by examining heart rate (HR) and blood pressure (BP), muscle fatigue, oxygen consumption, and lactic acid production. Work on the cycle ergometer was against loads of 300 kg and 600 kg meters per minute at cycle speeds of 30 rpm, 60 rpm, and 90 rpm. On the treadmill, work was performed against loads of 1500 and 2500 kg meters per minute, and the grades were 5%, 10%, and 15%. The results showed that work on the cycle ergometer at the lowest rpm and work at the highest incline on the treadmill were comparable. Work at the lowest and slowest loads required the highest energy consumption and caused the greatest increase in blood pressure, while heart rate only increased modestly when compared to these same measurements during a high-speed workout. This confirms the high static component of slow speed work. Using this information as the baseline, the static component of aerobic exercise during using three different Gliding exercise videos

Table 1. General Characteristics of Subjects

	Age (years)	Height (cm)	Weight (kg)	Resting Heart Rate	Resting BP* (Systolic)	Resting BP
(Diastolic)						
Mean	24.3	169.4	63.3	81.01	110.5	64.3
SD	0.5	5.8	10.3	15.1	6.4	4.4

*BP indicates blood pressure.

and during lunges with or without Gliding disks were calculated. Lunges with Gliding disks were associated with approximately a 20% increase in oxygen consumption and heart rate, and approximately a 30% reduction in hamstring and quadriceps muscle strength during 5 minutes of exercise compared to regular lunges without Gliding. The static component and total workloads were greater. In the exercise using the 15-minute, 13-minute, and 8-minute exercise videos with gliding, there was a high isometric component, which caused a substantial reduction in muscle strength. Exercise using Gliding disks with the videos has a high static component and provides a good aerobic training.

INTRODUCTION

It is hard to envision exercise that is strictly either dynamic or isometric in character. Dynamic exercise often results in a large increase in heart rate and ventilation, while mean blood pressure does not change during the workout.[1,2] The increase in respiration, heart rate, and blood pressure associated with dynamic exercise is due in large part to a mechanism called reflex in nature.[3] Depending on the frequency of exercise, there is some variability in ventilation and circulation during dynamic exercise.[4] While there is some difference associated with muscle fiber composition in these responses,[5] they are usually similar when compared to work normalized as a percent of the maximum oxygen consumption max VO_2, in both men and women and irrespective of race.[2]

At the other end of the spectrum is exercise where the muscle does not change length. This type of exercise is called isometric exercise. During isometric exercise, the ventilation increase is modest (a few liters per minute) but greater than that needed for oxygen delivery, thereby causing hyperventilation.[1] Systolic and diastolic blood pressure show a progressive and steady increase throughout the duration of the exercise such that blood pressure can increase by 50% or more during a 2 minute fatiguing isometric contraction.[6] A further delineating factor in isometric exercise is the fact that during isometric exercise, muscle strength decreases steadily throughout the exercise whereas during dynamic exercise strength is only marginally reduced unless the exercise is done to fatigue.[6]

When dynamic exercise is conducted slowly and against a heavy load (isokinetic exercise), even though the exercise is rhythmic, anaerobic metabolism dominates and the cardiovascular responses are closer to isometric then dynamic exercise.[7] Thus in exercise such as rock climbing, cardiovascular responses may not correlate well compared to pure aerobic exercise such as cycle ergometry at 60 rpm.[8] In dynamic exercise, there is less of an increase in heart rate and muscle heat production is higher during repeated bouts of exercise against heavy loads, than during high speed dynamic exercise.[9,10]

However, a previous study may explain these results. Petrofsky et al[11] examined the static component of rhythmic exercise. In these experiments, cycle ergometry was accomplished at the same absolute workload either at slow speeds (30 rpm), moderate speeds (50 rpm), or high speeds (90 rpm). For exercise at 90 rpm, the body exhibited responses associated with pure dynamic exercise whereas, at low speeds, muscles fatigued rapidly. Although the workloads were the same for all speeds, there was a lower heart rate response, less oxygen uptake, and greater muscle fatigue at low speed workouts compared to high-speed workouts even though workloads were matched. Thus, slow dynamic exercise may provide good strength training, although dynamic exercise is inherently known for cardiovascular effects and not for strength training.[2]

In summary, while isometric exercise is a pure form of exercise and the cardiorespiratory responses are predictable, the cardiovascular responses to dynamic exercise are not fixed, but show a spectrum of responses from that of very slow and heavy isokinetic exercise where the cardiovascular responses are similar to isometric exercise to high speed low load dynamic exercise where the heart rate and cardiac output increase greatly while muscle strength, and blood pressure respond more modestly. For exercise involving moderate loads at moderate speeds, the responses are between these extremes.[11]

Therefore, it seems reasonable that many types of exercise, which involve stabilization of the core muscles such as lunges (hip extension, flexion and adduction abduction exercises), have a significant static component, since to stabilize the core of the body, the abdominals and paraspinal muscles must be engaged in an isometric contraction to keep the trunk stable. The purpose of this study was to quantify the static component of rhythmic exercise during exercise videos and lunges compared to cycle ergometry and treadmill exercise. Two types of lunges were examined. One which involved hip extension on alternate sides of the body and the other, which still involved hip extension, but included the use of "Gliding" disks to allow the leg to move with low friction, thereby providing continuous muscle activity throughout the lunge exercise.[19] Three different exercise videos involving Gliding were also evaluated.

SUBJECTS

The subjects were 4 females. Their characteristics are summarized in Table 1. All subjects were fit thoroughly trained in treadmill, cycle ergometer, and aerobic lunge exercises. All subjects were free of cardiovascular or orthopedic impairments and all subjects had the experimental procedures explained to them and signed a statement of informed consent approved by the Human Review Committee at Azusa Pacific University.

METHODS

Strength

Isometric strength of the quadriceps and hamstrings muscles was measured with the subjects in the seated position and the leg held at a 90° angle. To accomplish this, a woven cotton belt was placed around the ankle and connected to an isometric strain gauge transducer bar. The strain gauge was linear in the range of 0 kg to 200 kg of force. The output of the transducer was amplified with a strain gauge conditioner amplifier with a gain of 1000. The output was stored and analyzed as the average strength over the middle of a 3 second maximum contraction.

Figure 1. A pneumotach is used to measure oxygen consumption and ventilation on a subject exercising. A nose clip is used to ensure airflow through the mouth only.

Oxygen Consumption, Ventilation, Carbon Dioxide Production, Respiratory Quotient
A VO-2000 portable metabolic cart (Aerosport Inc., Minneapolis, Minn) was used in these studies. The analyzer is composed of a battery operated metabolic cart containing a CO_2 infrared analyzer, a fuel cell based oxygen analyzer, and a pneumotach (Figure 1). The analyzer was calibrated with the local barometric pressure and temperature at the beginning of each day. The analyzer sampled expiratory gases through a mouthpiece. The subjects wore a nose clip to assure all expiratory gasses passed through the pneumotach. The gas was sampled breath by breath and all gas values were averaged over a 20-second period. Ventilation, oxygen consumption, and carbon dioxide production were then converted to standard pressures and temperatures (STPD) and stored in the memory of the analyzer.

Blood Lactate
An Accusport fingertip lactic acid analyzer measured blood lactate. The blood sample was taken from arterialized blood in the subject's fingertip 5 minutes after exercise; total blood volume was 25 μL. Blood was arterialized by placing the hand in warm water for 5 minutes, immediately following exercise, before the sample was taken (Figure 2).

Heart Rate
Heart rate was recorded from palpitation of the radial pulse.

Blood Pressure
Blood pressure was measured by auscultation of the left arm with a blood pressure cuff. The cuff was pumped to 200 mmHg and deflated at 3 mmHg per second as per the standards of the American Heart Association. Systolic blood pressure was assessed as the first tapping sound heard through a sphygmomanometer in the anacubical fossa. Diastolic pressure was the change in pitch from the high pitch tapping to a murmur. The same person measured blood pressure on all occasions (Figure 3).

Statistical Analysis
Statistical analysis involved the calculation of means, standard deviations, and paired and unpaired *t* tests. The level of significance was $P < 0.05$.

PROCEDURES
Four series of experiments were accomplished. In the first series of experiments, the relationship between oxygen

Figure 2. A subject's hand is placed in warm water on a hotplate to arterialize the blood in the fingertip prior to sampling blood for lactic acid determinations.

Figure 3. Blood pressure measured on a study subject.

consumption, heart rate, blood pressure, and muscle fatigue in the quadriceps and hamstring muscles was determined during treadmill running. Treadmill running was performed at 2 different workloads with the treadmill set at 3 different grades (5%, 10%, and 15%) (Table 2). The speed was adjusted for each individual, so that workloads were matched at each grade at either 1500 kg meters per minute or 2500 kg meters minute. Because of differences in body weight, the speed was different for each subject. Table 2 shows the average speeds at each grade with the standard deviations for the group. In this manner, on the treadmill, the same workloads and the cardiovascular responses could be measured with fast running at a low incline, versus high incline and slow running. Subjects exercised for periods of 5 minutes and between the fourth and fifth minute of exercise, oxygen consumption, respiratory quotient, and ventilation were measured. After the exercise was over, lactates, blood pressure, and heart rate were assessed, as were changes in the muscle strength in the quadriceps and hamstring muscles (Figure 4). The strength was measured within a few seconds after the end of each exercise.

In the second series, the experiments were repeated on a cycle ergometer. Speeds of 30 rpm, 60 rpm, and 90 rpm were used with various workloads to allow work at 300 kg meters/min and

Table 2. Average Speeds Used for the Treadmill

	Speed 5% grade (miles/hour)	Speed 10% grade (miles/hour)	Speed 15% grade (miles/hour)
Low mean	1.8	0.9	0.6
Low standard deviation	0.3	0.1	0.1
Medium load	5.9	3.0	2.0
Medium standard deviation	1.0	0.5	0.3

Table 3. Workloads on Cycle Ergometer

	Low resistance (300 kg m/min)	Moderate resistance (kg m/min)
30 rpm	1.67	3.33
60 rpm	0.83	1.67
90 rpm	0.56	1.11

600 kg meters/min for each speed (Table 3). Protocols were similar to those above. Subjects exercised for periods of 5 minutes and between the fourth and fifth minute of exercise, oxygen consumption, respiratory quotient, and ventilation were measured. After the exercise was over, lactates, blood pressure, and heart rate were assessed, as were changes in the muscle strength in the quadriceps and hamstring muscles.

In the third series of experiments, subjects engaged in exercise involving alternating leg hip extension (lunges) with or without discs (Gliding) under the foot to reduce friction upon movement (Figure 5).

Finally, in the fourth series of experiments, subjects followed a video exercise program provided by Savvier LP (Santa Fe Springs, Calif). Subjects used Gliding disks to minimize kinetic friction between the body and the floor. Gliding, by minimizing friction, allows smooth muscle contraction during movement in any direction with continuous muscle activity (Figure 5).[19] The videotape was divided into 3 segments. The first (15 minutes) and second (13 minutes) Gliding segments involved rhythmic lunge sequences in the standing position. The third Gliding segment involved exercise on the floor in the prone and side lying positions for a total of 8 minutes. For each segment, the parameters above were measured in the fourth, fifth, and last minute of exercise except for strength and lactate measurements, which were done at the end of the exercise.

RESULTS

Treadmill Exercise

The results of the studies on treadmill ergometry are shown in Figure 6. Heart rate was highest and blood pressure lowest during a workout at a 5% grade. The average increase in heart rate during exercise at a load of 1500 kg meters per minute was 22 ± 9.38 beats per minute for work at a 5% grade (Figure 6B). At 2500 kg meters per minute of resistance, the heart rate increased by 43.5 ± 23.69 beats per minute. In contrast, exercise with the treadmill (Figure 7) at a 15% grade showed a more modest increase in heart rate, 15 ± 4.76 beats per minute at the lowest load, and 27.5 ± 7.63 beats per minute at the moderate load. In contrast, systolic blood pressure was highest

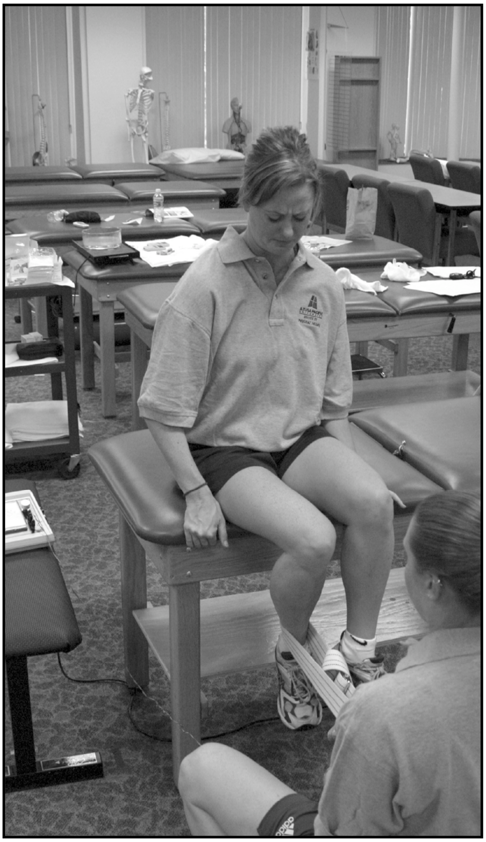


Figure 4. Hamstring muscle strength measured immediately after an exercise bout.

Figure 5. A subject using Gliding to accomplish backward lunges. When the heel is planted on the floor (front) one leg is fixed and cannot move, with the heel lifted, Gliding provides very low friction, so that the leg can traverse into extension and flexion with continuous smooth muscle activity.

for the moderate workload at a 15% grade. For example, the change in systolic blood pressure at the moderate workload for the 15% grade was 19.5 ± 8.02 mmHg compared to 10.0 ± 2.94 mmHg for the same workload at the 5% grade. Thus, for the cardiovascular responses, matched workloads at a 15% grade resulted in a greater increase in blood pressure, but had less effect on heart rate compared to matched workloads at the lowest grade examined. These differences were significant ($P < 0.01$). Workloads at the 10% grade fell between the two extremes. Diastolic blood pressure was not significantly different at any workload examined. ($P > 0.05$, ANOVA)

The greatest increase in lactates occurred at the 15% grade and at a moderate workload (15% grade, 2500 kg meters per minute workload). Here, the average lactates increased by 2.3 ± 1.4 mmoles/L compared to the similar workload at a 10% grade, where lactates only increased by 0.88 ± 0.4 mmoles/L. At the same workload at the 5% grade, the lactates increased much more modestly by 0.05 ± 0.23 mmoles/L. When muscle strength was measured before and after exercise at the 6 workloads examined here, there was a reduction in strength for both the quadriceps and hamstrings muscles after all workloads. Prior to exercise, the average strength of

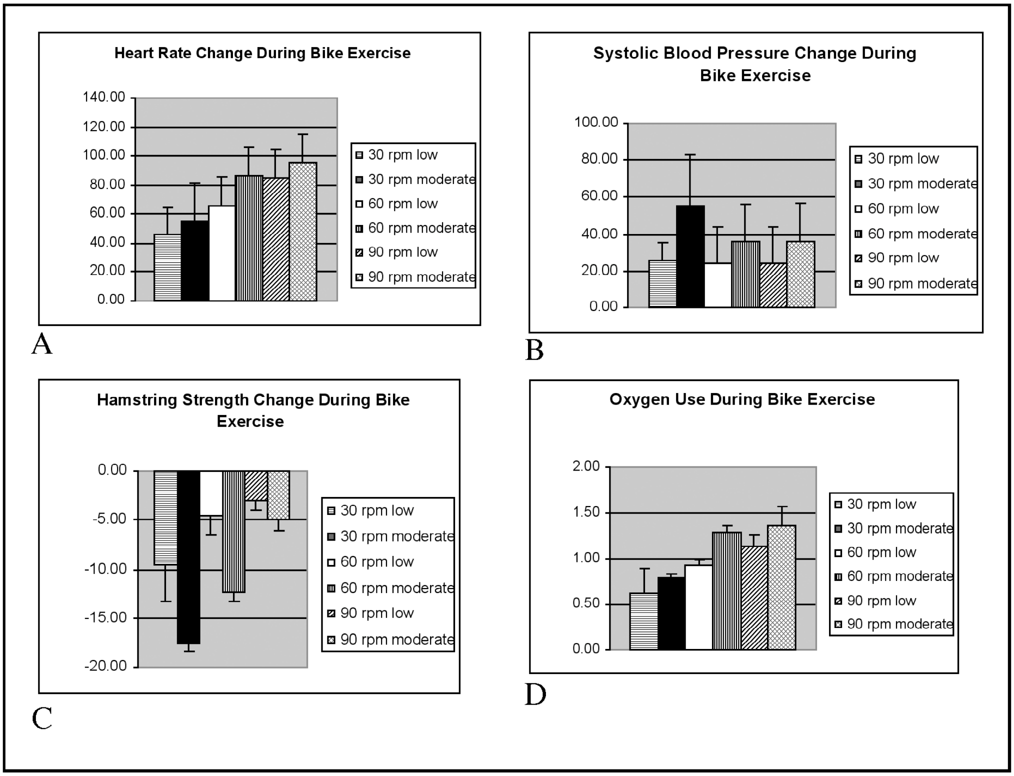


Figure 6. A) Heart rate, B) systolic blood pressure, C) hamstring strength, and D) oxygen consumption during exercise on a cycle ergometer at speeds of 30 rpm, 60 rpm, and 90 rpm against workloads at each speed of 300 and 600 Kg meters/min.

the quadriceps muscles during extension of the leg, measured at the ankle, was 61.17 ± 17.6 kg. For the hamstring muscles, the average strength was 42.6 ± 5.93 kg. At the end of the exercise, the reduction of the quadriceps muscle strength was greatest for workloads at the 15% grade and lowest for exercise at the 5% grade. For example, at the lowest grade (5%), the reduction in quadriceps strength was 2.5 ± 1.08 kg for the low workload, whereas the reduction was 4.0 ± 3.2 kg for the moderate workload. In contrast, for exercise at the highest grade (15%), the reduction was 7.5 ± 5.0 kg for the low workload, and 12.8 ± 9.3 kg for the moderate workload. The same relationship was seen for the hamstring muscles (Figure 6C). There was a sharp reduction in the strength of the hamstring muscle associated with all workloads. Expressed as a percent, at a 5% grade, there was a 2.48% loss in strength for the low workload compared to a 5.88% loss for the moderate workload. For the 10% grade, there was a loss in strength of 6.1 after the low workload and 10.1% after the moderate workload. At a 15% grade, the reductions in strength were 7.4% after the low workload and 17.2% after the moderate workload.

The respiratory responses showed a similar pattern. The oxygen consumption was greatest for work at a grade of 5% and lowest for a grade of 15% (Figure 6D). When subjects ran at a grade of 5% with a moderate workload, the oxygen consumption averaged 1.29 L/minute (6.45 calories), whereas the oxygen consumption at a higher grade (15%) averaged only 0.83 L/minute (4.15 calories) in the last minute of exercise (Figure 6B). During this same period, at the moderate workload, ventilation showed similar responses with ventilation against a 5% grade increasing to 35.6 ± 15.4 L/min, whereas at a 15% grade ventilation was 19.36 ± 1.56 L/min.

Cycle Ergometer Exercise

The results of the experiments on the cycle ergometer are shown in Figures 7A, B, C, and D. The largest increase in heart rate was after work at 90 rpm compared to matched work at either 30 rpm or 60 rpm (Figure 7A). The differences between the low workloads at 30 rpm, 60 rpm, and 90 rpm were statistically significant, as was data for the moderate workloads at 30 rpm, 60 rpm, and 90 rpm ($P < 0.05$). The increases in heart rate for work at 90 rpm was nearly double that of 30 rpm. The same was true concerning blood pressures (Figure 7B). The average systolic blood pressure for the group was much higher for work at 30 rpm than 90 rpm. This difference was statistically significant ($P < 0.05$). For example, at a moderate load, at 30 rpm the average increase in systolic blood pressure was 55.3 ± 11.8 mmHg, whereas at 90 rpm, the increase in systolic pressure was only 36.5 ± 6.2 mmHg. Thus at a moderate workload, the average blood pressure for subjects increased from an average of 114 ± 2.4 mmHg at rest to an average of 150 ± 8.16 after work at 90 rpm, but only increased to an average of 168.8 ± 10.3 mmHg at 30 rpm. Therefore, as was the case for treadmill ergometry, the cardiovascular responses were a function of the speed of work.

At a moderate workload, the greatest increase in lactates occurred at 30 rpm; the average lactates increased by 3.9 ± 5.3 mmoles/L compared to 60 rpm where lactates only increased by 1.4 ± 2.1 mmoles/L. At 90 rpm, the lactates increased much more modestly by 0.17 ± 0.91 mmoles/L.

Changes in strength were also telling. For the group, the average reduction in strength was greatest at 30 rpm compared to 60 rpm and 90 rpm; these differences were statistically significant (ANOVA, $P < 0.01$) (Figure 7C). The greatest reduction in strength occurred at 30 rpm at the moderate workload. For the quadriceps muscle, for example, muscle strength was reduced from the initial average of 75.5 ± 20.4 kg before exercise to 59.8 ±17.7 kg after moderate exercise at 30 rpm, a loss of 15.8 ± 3.5 kg. In contrast, after the same moderate work at 90 rpm, strength of the quadriceps muscle was reduced by 7.75 ±13.0 kg, a much more modest reduction in strength. The same relationship was seen for the hamstring muscles (Figure 7C). Here the greatest reduction in strength for either the low or moderate workload was at the lowest rpm. These differences for the hamstring muscle between the three different cycling speeds are statistically significant ($P < 0.01$).

Finally, the greatest oxygen consumption and ventilation occurred after exercise at 90 rpm (Figure 7D). Oxygen consumption was highest after exercise at 90 rpm and lowest at 30 rpm; when comparing the oxygen uptake during the low workload at 30 rpm versus 60 rpm versus 90 rpm, the differences were statistically significant ($P < 0.01$), as was the comparison of oxygen consumption during moderate workloads at 30 rpm, 60 rpm, and 90 rpm ($P < 0.01$). For the lowest workload at 30 rpm, the increase in ventilation was 15.83 ± 0.92 L/min, whereas at 90 rpm, the increase in ventilation averaged 35.83 ± 9.1 L/min. Thus for ventilation and oxygen consumption, the greatest demand on the respiratory system was at 90 rpm with the demand at 30 rpm being only about 50% of that at 90 rpm.

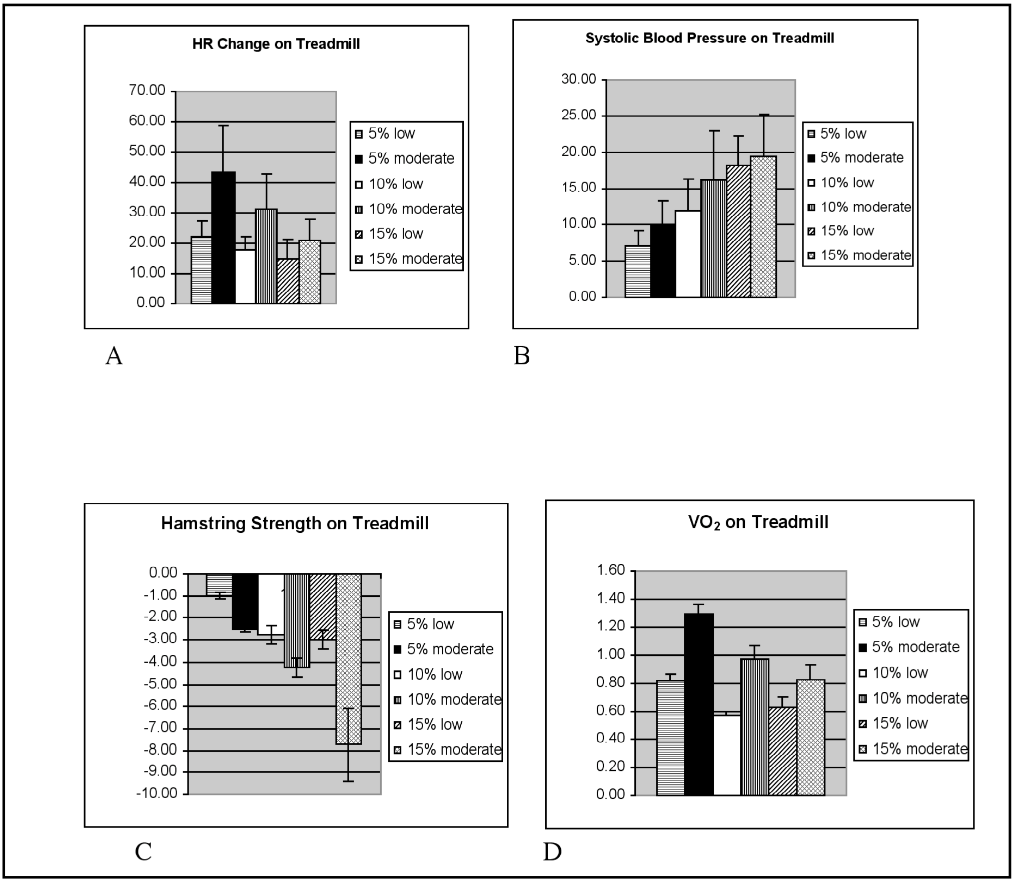


Figure 7. A) Heart rate, B) systolic blood pressure, C) hamstring strength, and D) oxygen consumption during exercise on a treadmill against a grade of 5%, 10%, and 15% with low and moderate exercise loads.

Exercise Videos And Lunges

Data from the third and fourth series of experiments have been analyzed together, since both involved Glides (Figures 8 and 9).

The increase in heart rate associated with 5 minutes of hip extension (lunges) with Gliding or without Gliding, and following the Gliding videos lasting 15 minutes, 13 minutes, and 8 minutes are shown in Figures 8 and 9. There was no statistical difference in oxygen consumption, heart rate or ventilation during aerobic exercise during the 3 Gliding exercise videos, when comparing the data at 5 minutes to that in the last minute of exercise ($P > 0.05$). Therefore, only data in the last minute is presented in the paper.

The heart rate was substantially increased for all five types of exercise. Comparing 5 minute hip extension data with Gliding (HEG) to without Gliding (HE), the increase in heart rate averaged 54.0 ± 10.9 beats/minute at the end of 5-minutes HEG compared to 30.0 ± 14.7 beats/min at the end of HE. The difference between the two was significant ($P < 0.01$) (Figure 8A). In contrast, the average heart rate at the end of Gliding exercise using the 15-, 13-, and 8-minute videos was greater than that of lunges, but similar to that of Gliding lunges. The difference between the heart rate, for

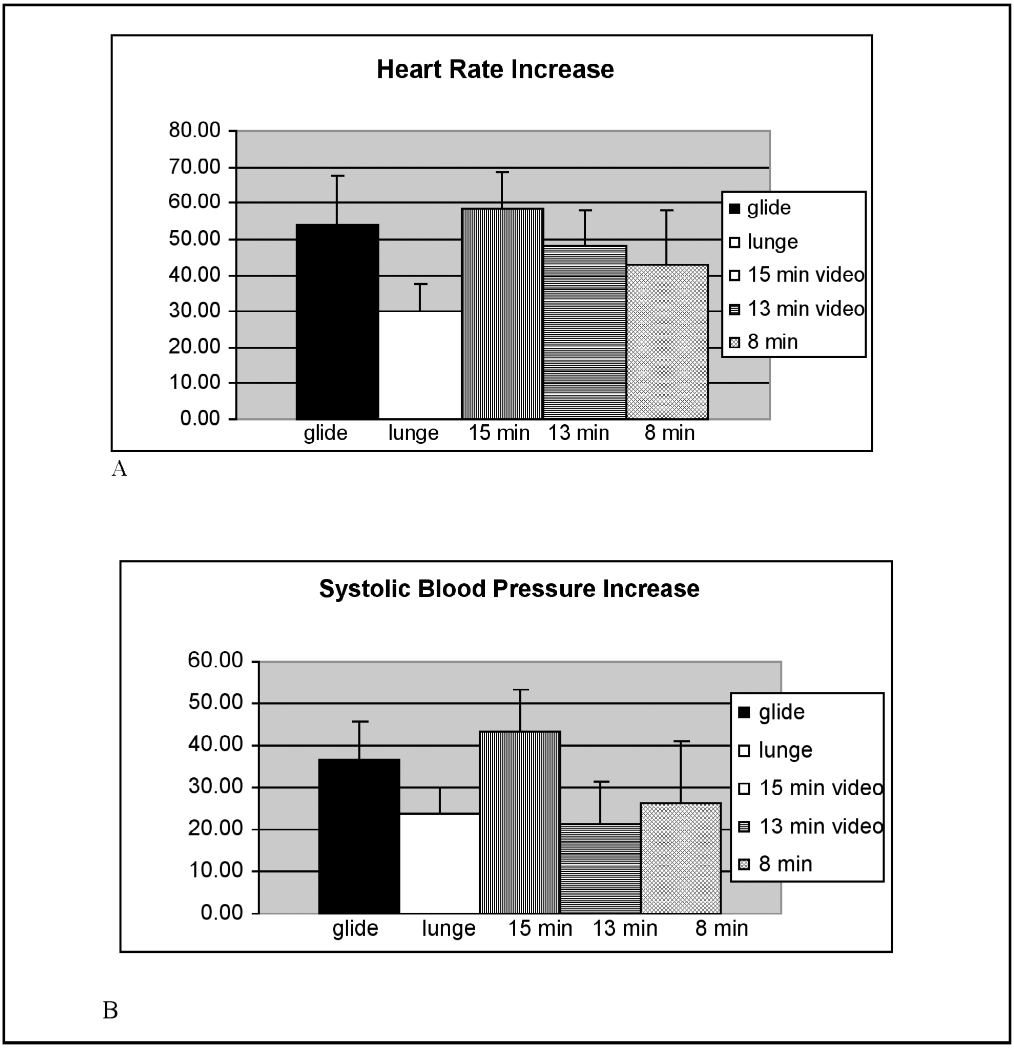
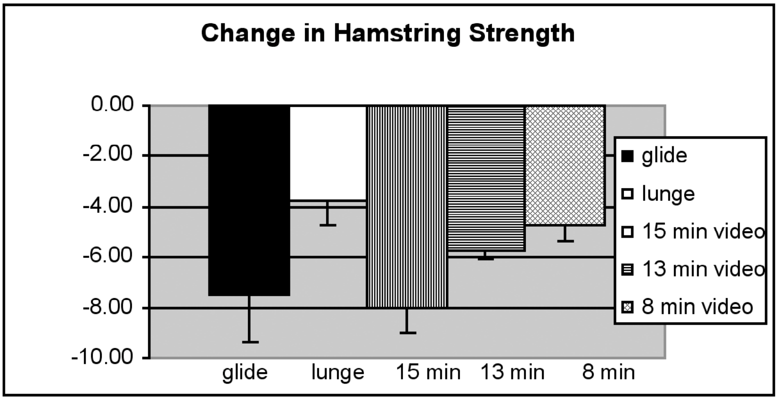


Figure 8. The change in heart rate (A) and systolic blood pressure (B) during 5 minute bouts of hip extension Gliding, 5-minutes of hip extension lunges, and exercise using the 15-minute, 13-minute and 8-minute video Gliding exercise programs.

lunges with or without Gliding, or Gliding using the 15- and 13-minute exercise videos, were not statistically significant ($P < 0.05$). However, the heart rates at the end of the Gliding exercise using 8-minute video were greater than after lunges without gliding, but less than after lunges with Gliding ($P < 0.05$) The diastolic blood pressure was unaffected by any of the different exercises. However, the systolic blood pressure was statistically higher for HEG than for HE ($P < 0.05$) (Figure 8B). Systolic blood pressure at the end of Gliding exercise, using the 13- and 8-minute videos, was not different than at the end of lunges without Gliding ($P > 0.05$), but less than that of the 15-minute video exercise using Gliding ($P < 0.05$).

The lactates recorded after the backward lunges without the glides averaged 0.4 ± 1.1 mm/L, whereas for



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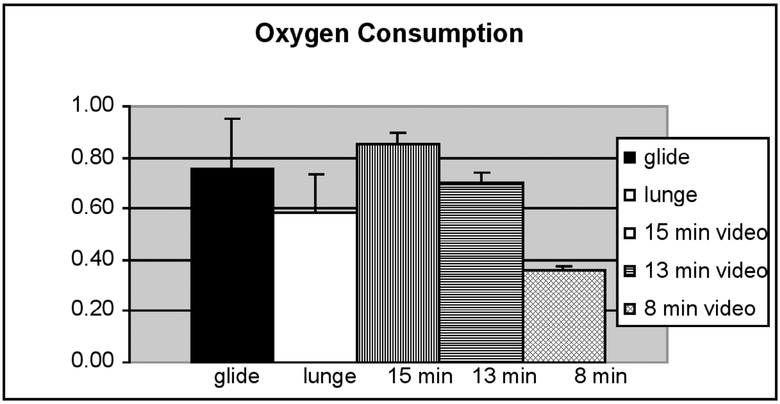

B

Figure 9. The change in hamstring strength (A) and oxygen consumption (B) during 5 minute bouts of hip extension Gliding, 5-minutes of hip extension lunges and exercise using the 15-minute, 13-minute and 8-minute video Gliding exercise programs.

back lunges with the glides, the average lactates were 0.7 ± 0.34 mm/L. In contrast, for the 3 Gliding exercise videos, the lactates at the end of exercise were 1.1 ± 1.29, 0.63 ±1.09, and -0.05 ± 0.13 mm/L for the 15-, 13- and 8-minute exercise segments, respectively.

As shown in Figure 9, the reduction in strength of the quadriceps and hamstrings muscles was greatest during Gliding lunges and after using the 15-minute Gliding exercise video and lowest after back lunges and the using the 13- and 8-minute Gliding exercise videos. For example, for the quadriceps muscle, the reduction in strength after lunges with Gliding was 9.3 ± 6.9 kg whereas after the lunge exercise it was 3.2 ± 3.6 kg. Hamstring data showed a similar reduction (Figure 9A). The difference between the strength in the quadriceps and the hamstring muscles after the lunges with Gliding versus lunges was statistically significant ($P < 0.05$).

Oxygen consumption was higher during lunges with Gliding than lunges without gliding. The average oxygen consumption for the group after the lunges with Gliding averaged 0.76 ± 0.18 L/min (3.8 ± 0.9 calories) and after lunges without gliding averaged 0.59 ± 0.11 L/min (2.95 ± 0.55 calories).

Of the 3 Gliding exercise videos, oxygen consumption was highest for the 15-minute video, almost as high for the 13-minute video, and lowest for the 8-minute video (Figure 9B). The respiratory quotient during the 3 videos, averaged 0.79 ± 0.6 demonstrating that the exercise was supported by the metabolism of lipids.

DISCUSSION

The benefits of sustained bouts of exercise for health and physical conditioning are well documented.[12,13,14] While exercise is difficult for people with disabilities,[15] even in patients with heart failure, exercise training improves mortality and reduces morbidity.[16]

However, what is called aerobic exercise in many of these studies is actually a complex combination of stress on anaerobic and aerobic metabolic pathways. Slow exercise conducted rhythmically still has a considerable isometric component.[11] Exercise conducted at low contraction frequencies and high loads versus high frequencies and low loads are characterized by very different physiological responses even if the work is matched.[10,11] For example, for slow exercise conducted at a heavy load, blood pressure and ventilation are higher and muscle fatigues more rapidly than for high speed work at light loads.[6,11] The greater demand placed on the anaerobic capacity of the muscle by slow exercise may be partially due to the fact that during dynamic exercise, especially with heavy loads, muscle is perfused poorly due to high intramuscular pressure.[17] Slow aerobic exercise, by decreasing muscle strength, adds a strength training component to dynamic exercise.[18,11] In contrast, aerobic exercise at a light load does little to build muscle strength, but is a good for building aerobic capacity.[2] Thus a workout program involving slow heavy exercise and fast light exercise together should provide both cardiovascular conditioning and strengthening of the muscle.

In the present investigation, the relationships reported previously in cycle ergometry were confirmed concerning a high loss in muscular strength with slow rhythmic exercise.[11] Cycle ergometry conducted at a slow rate but heavy load resulted in considerable production of lactic acid and a disproportional increase in ventilation, heart rate and blood pressure during exercise. In contrast, cycle ergometry at a high rate but low load produces only small changes in mean blood pressure and little lactic acid. This same relationship was seen in treadmill ergometry. On the treadmill, running at a 15% grade resulted in considerable losses in muscle strength and increases in blood pressure, ventilation, and heart rates, as well as lactic acid production, all indicative of a high component of anaerobic or static exercise. Exercise at the same workloads, with the treadmill at a lower grade, even at matched workloads, produced much less of an increase in lactic acid, oxygen consumption, and loss of muscle strength. This confirms the low static component of the exercise.

It is not surprising, then, that a mixed workout, which is, comprised of a 15-minute exercise period of high- and low-speed aerobic exercise involving Gliding falls in between the two. The reduction of muscle strength and the changes in heart rate and ventilation show that this form of exercise falls in the middle of the two, being a mixture of anaerobic (static) exercise, which builds muscle strength, and pure aerobic exercise, which tones the cardiovascular system. Using cardiovascular measures, a mixed exercise is quantified in terms of its anaerobic and aerobic component. This static component of rhythmic exercise is essential to compute in any exercise program to minimize the time needed for training. With the reductions in muscle strength in such a program, a separate weight lifting program would not be a necessary, since the exercise itself becomes a total body workout.

For Gliding, the heart rate increase was slightly greater than that of the moderate workload on the treadmill (3500 kpm/minute) at a 5% grade. Since exercise at a 5% grade is associated with pure aerobic exercise with little static component, this would seem to imply that Gliding is associated with a large static component. However, the increase in blood pressure was 35 mmHg and equivalent to exercise at a 15% grade on the treadmill or cycle ergometer (Figure 8B). Further, on the treadmill, the loss in hamstring strength was greater than that seen at a 5% grade, but almost equivalent to the moderate load at the 15% grade. This is also true of oxygen consumption, which was low for the level of heart rate shown and muscle loss seen in the exercise. Thus, Gliding is a mix of aerobic exercise with a high isometric or static component. This high static component will provide good strength training along with endurance training during Gliding lunges. The opposite was true of regular lunges where the loss in strength was equivalent to almost pure aerobic exercise on either the treadmill (Figure 6) or cycle ergometer (Figure 7), while the work was much less.

The results of exercise following the 15-minute video, which involved exercise in the standing posture with Gliding, showed a greater increase in oxygen consumption and a greater loss in strength than with the 13-, and 8-minute Gliding videos. Oxygen use (0.8 L/minute, 4 calories) during treadmill or cycle ergometry, increased to 0.8 L/per minute (4 calories) for pure aerobic exercise with a low static component (eg, exercise on the treadmill up to 5% grade or on the cycle ergometer at 90 rpm) and would cause significantly less strength loss than Gliding. The greater loss in strength along with greater increase in systolic blood pressure with Gliding exercise using the video would indicate that this video exercise has a high muscle strength-training component. This was also seen with the 13-minute and 8-minute Gliding video exercise but to a smaller extent. The 8-minute Gliding video exercise appeared to be higher in the pure aerobic exercise component than exercise with the 15-minute video. However, exercise following all three Gliding videos did have a much higher isometric component than treadmill ergometry against a 5% grade or bicycle ergometry at 90 rpm.

Comparing treadmill ergometry to the exercise following the 15-minute Gliding video, the response of oxygen consumption and reductions in strength using the video workout seemed to be equivalent to exercise on a treadmill ergometer at a 15% grade with the load of 2500 kpm/minute (Figures 6 and 9). The easiest workout, following the 8-minute video, corresponded to exercise on a treadmill at a 15% grade and a workload of 1500 kg/minute. In other words, the workout using the 15-minute Gliding exercise video was equivalent of running up a 15% grade at two miles an hour, whereas exercise following the 8-minute exercise video was equivalent to running up hill at .5 miles per hour (Table 2). On the other hand, the Gliding exercise was highly aerobic in nature, as demonstrated by oxygen consumption and lactic acid production.

Thus Gliding was in the middle of the spectrum between pure aerobic and pure weight lifting exercise, being a mixture of both. Therefore, exercise using these videos provided a heavy dynamic workout as well as implied strength training because of their high static component.

In 1998, The American College of Sports Medicine published guidelines for exercise levels to maintain cardiovascular fitness.[20] They recommended exercising 3 to 5 days per week at an intensity of 55% to 65% maximum heart rate reserve or 4 METS or about 50% VO_2 reserve for up to 60 minutes.[21] In the present investigation, the Gliding video exercise could be analyzed several ways. In terms of METS, the average resting oxygen consumption was 0.19 liters per minute. The oxygen consumption using the 15-minute Gliding video was 0.8 liters per minute or 4.2 METS. Thus under the METS classification, the workload would be classified as moderate and would pass ACSM guidelines for cardiovascular training. The same would be true of the 13-minute Gliding video exercise.

Using heart rate, an increase of 60 beats per minute would place the exercise in the moderate workload category as per ACSM guidelines for fitness. The increase in heart rate after the 15-minute video workout was only 55 beats per minute and slightly less with the other 2 videos. Unlike most exercise, there was a high static component when exercising using the 13- and 15-minute Gliding exercise videos, which causes a reduction in heart rate to a value less than the equivalent workload with pure aerobic exercise. Thus by the heart rate standard, exercise using the 15- and 13-minute Gliding videos meet the standard for moderate exercise intensity required by ACSM guidelines. The 8-minute Gliding video exercise would be classified as a light workout, using heart rate and oxygen consumption.

REFERENCES

1. Wiley RL, Lind AR. Respiratory responses to simultaneous static and rhythmic exercise in humans. *Clin Sci Mol Med.* 1975;49(5):427-432.
2. McArdle WD, Katch FI, Katch VL. Energy, Nutrition, and Human Performance. In: *Exercise Physiology.* 5th ed. Philadelphia, Pa: Lippincott, Williams & Wilkins; 2001:chap 3.
3. Tallarida G, Baldoni F, Peruzzi G, Raimondi G, Massaro M, Sangiorgi M. Cadiovascular and respiratory reflexes from muscles during dynamic and static exercise. *J Appl Phsiol.* 1981;50(4):784-791.
4. Miyamoto Y, Nakazono Y, Yamakoshi K. Neurogenic factors affecting ventillatory and circulatory response static and dynamic exercise in man. *Jpn J Physiol.* 1987;37(3):435-446.
5. Suzuki Y. Mean arterial pressure, O_2-uptake, and muscle force time during dynamic and rhythmic-static exercise in men with high percentage of fast- and slow-twitch fibers. *Eur J Appl Phsiol Occup Phsyiol.* 1980;43(2):143-155.
6. Petrofsky JS. *Isometric Exercise and Its Clinical Implications.* Springfield Ill: Charles C Thomas; 1982.
7. Martin BJ, Chen HI, Kolka MA. Anaerobic metabolism of the respiratory muscles during exercise. *Med Sci Sports Exerc.* 1984;16(1):82-86.
8. Sheel AW, Seddon N, Knight A, Mckenzie DC, Warburton DER. Physiological Responses to Indoor Rock-Climbing and Their Relationship to Maximal Cycle Ergometry. *Med Sci Sports Exerc.* 2003;35(7):1225-1231.
9. Krustrup P, Gonzalez-Alonso J, Quistorff B, Bangsbo J. Muscle heat production and anaerobic energy turnover during repeated intense dynamic exercise in humans. *J Physiol.* 2001;536:947-956.
10. Furguson RA, Ball D, Krustrup P, et al. Muscle oxygen uptake and energy turnover during dynamic exercise at different contraction frequencies in humans. *J Physiol.* 2001;536:261-271.
11. Petrofsky JS, Rochelle RR, Rinehart JS, Burse RL, Lind AR. The assessment of the static component in rhythmic exercise. *Eur J Appl Phsiol Occup Physiol,* 1975;34(1):55-63.
12. Ko GT. Short-term effects after a 3-month aerobic or anaerobic exercise programme in Hong Kong Chinese. *Diabetes Nutr Metab.* 2004;17(2):124-127.

13. Copeland JL, Chu SY, Tremblay MS. Aging, physical activity, and hormones in women—a review. *J Aging Phys Act.* 2004;12(1):101-116.

14. Raurmaa R, Halonen P, Vaisnen SB et al. Effects of aerobic exercise on inflammation and atherosclerosis in men: the DNASCO Study: a six-year randomized controlled trial. *Ann Intern Med.* 2004;140(12):1007-1014.

15. Romberg A, Virtanen A, Aunola S, Karppi SL, Karanko H, Ruutiainen J. Exercise capacity, disability and leisure physical activity of subjects with multiple sclerosis. *Mult Scler.* 2004;10(2):212-218.

16. Smart N, Marwick TH. Exercise training for patients with heart failure: a systematic review of factors that improve mortality and morbidity. *Am J Med.* 2004;116(10):714-716.

17. Eiken O. Responses to dynamic leg exercise in man as influenced by change in muscle perfusion pressure. *Acta Physiol Scand Suppl.* 1987;566:1-37.

18. Bloomer RJ, Goldfarb AH. Anaerobic exercise and oxidative stress: a review. *Can J Appl Physiol.* 2004;29(3):245-263.

19. Petrofsky JS, Hill J, Jorritsma R, Bonacci J, Morris A, Hanson A. Muscle Use during Low Impact Aerobic Exercise (Gliding) Compared to Conventional Weight Lifting Equipment, Part 2. *J Appl Res*. In press.

20. Jakicic JM, Clark K, Coleman E, et al. Appropriate intervention strategies for weight loss and prevention of weight regain for adults. *Med Sci Sports Exerc.* 2001;33(12):2145-2145.

21. American College of Sports Medicine Position Stand. The recommended quantity and quality of exercise for developing and maintaining cardiorespiratory and muscular fitness, and flexibility in healthy adults. *Med Sci Sports Exerc*. 1998;30:975-991.